RADARSAT-1 Background Mission Monitoring of the Arctic

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***Abstract*- RADARSAT-1 baseline data acquisition planning has been performed for the past nine years under the Canadian Space Agency's Background Mission. Background Mission is about building uniform, global archives in support of RADARSAT-1 Program objectives of time- and site-specific data collections. Most of these objectives were met in the first five years of the nominal mission duration. An extended phase of Background Mission is under way, the most important element of which is a continuous four-season coverage of the Arctic Basin. This paper reports on the progress of this coverage campaign, which started in mid-2003, and has since been implemented uninterruptedly for summer, fall, winter and spring snapshots of the northern polar cap and a large area around it. It is expected that the systematic, sustained RADARSAT Background Mission coverage of the Arctic would result into valuable temporal records of a part of the world that is particularly sensitive to global climate change.**

I. INTRODUCTION

RADARSAT-1 Background Mission commenced in early 1996 [1,2], soon after the spacecraft commissioning and the start of operations, and has since resulted in one of the largest systematically collected Synthetic Aperture Radar (SAR) data archives. The very first Mission coverage was completed over the world's continents, continental shelves and polar caps using ScanSAR Wide beam mode of RADARSAT-1, with 500 km-wide swath and 100-metre pixel resolution. This was followed selectively by a 300 km-wide swath and 50-meter pixel ScanSAR Narrow coverage of the continental regions previously imaged with ScanSAR Wide beam. A global land stereo coverage was planned alongside the ScanSAR coverage with two independent RADARSAT-1 beams of 25-metre pixel spacing. First a region was covered with shallow incidence angle Standard 7 beam (45^o to 49^o), and then with the second beam. The second beam of steep incidence angle (24^o to 40^o) was chosen from among Standard 2, Standard 4 and Wide 2 beams of RADARSAT-1. Details on the various RADARSAT-1 imaging modes can be obtained from [3]. The on-board data storage facility of the spacecraft was availed to acquire also multi-seasonal and multi-year data over the remote oceanic islands; it was realized that these small oceanic entities, particularly those at higher latitudes, served as important indicators of changes in Earth's environment. The high-resolution RADARSAT-1 Fine beams with better than 10-metre pixel size were used to cover most of the world's major cities and metropolitan areas with the purpose of creating benchmarks for future urban change monitoring.

The RADARSAT-1 operations are now in their 10^{th} year, well past the 5-year design life of the satellite. Having met most of the baseline data acquisition targets within the nominal Mission duration, an Extended Background Mission Plan (EBMP) was prepared and implemented to continue enriching the archives with multi-mode RADARSAT-1 data and maximizing the exploitation of this valuable imaging resource.

II. MISSION RATIONALE

The RADARSAT-1 imaging system was designed specifically for cryospheric applications, such as sea ice monitoring, in regions where weather and illumination conditions may not allow optimization of the use of other sensors [3]. The original design consideration has remained by and large valid after 9 years of satellite operations. Consequently, the Canadian Ice Services have been the principal user of RADARSAT-1 data and the coverage of the Polar Regions the most important data acquisition project. The RADARSAT-1 Antarctic Mapping Mission (AMM) has proved beyond doubt the scientific value of RADARSAT-1 data and the success of the satellite mission [4]. An equally dedicated coverage of the northern polar cap in the final stages of the satellite operations would be a befitting affirmation of the earlier mission successes. Therefore, the Background Mission coverage was extended to include on an ongoing basis acquisition of seasonal ScanSAR Wide data of the entire northern circumpolar region, hitherto called the Arctic Basin. There has been no concerted effort so far to monitor systematically on a seasonal basis the geographical region of the northern circumpolar ice cap and its margins, apart from the routine surveillance done by the Canadian, American and European authorities in some portions of the region. The data acquisition over the entire basin is expected to attract the attention of operational agencies and scientific communities, and the neatness of the results obtained may justify continuation of the mission into RADARSAT-2 era.

A. Coverage beam

ScanSAR Wide is the RADARSAT-1 beam mode of choice for synoptic viewing of sea ice conditions. Most of the data acquisition planning requests for northern surveillance and operational support use this beam mode. The use of ScanSAR beams ensures timely and speedy coverage of a vast area, such as the Arctic Basin region, where coverage planning within strict seasonal limits is required. Moreover, the likelihood of

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conflicts with the operational users of RADARSAT-1 data in Canada, the U.S.A. and Europe is minimized because the same ScanSAR beam mode is used for data acquisition planning. ScanSAR Wide B beam has been retained for the Background Mission coverage. This has been done to reduce data dropouts at the margins of the direct station reception masks in the case of ScanSAR Wide A beam, despite the relatively larger imaging surface of the latter.

In order to enhance the information content in terms of monitoring of the environmental dynamics of sea ice and polar ice cap, four-season coverage has been planned for every year. In the Background Mission planning priorities, a provision has however been made to reduce the effort to only summer and winter coverage in the event of reduced availability of the imaging resource. This has been done to obtain satellite imagery of minimum and maximum ice extent.

B. Coverage Area

In so far as the geographical limit of the coverage area is concerned, a natural delineation of the southern boundary of the region was considered. The 10^{o} July isotherm was chosen as the southern boundary. There are three main markers that could be used to define the boundary: The Arctic Circle, a climatic marker, or a vegetational marker. The Arctic Circle is simply the area of mid-night sun and has no bearing on the ecological or cryospheric data applications. It leaves out a large portion of the northern polar cap. The vegetational boundary, delineated by the treeline, or the boundary between the Tundra and the (Boreal) forest alone is not appropriate as it is subject to strong variations in response to local climatic effects caused by sea currents, winds and soil conditions. For example, the width of this boundary varies highly, from being a narrow strip in North America to a 300 km-wide zone in Eurasia. The 10^{o} isotherm climatic boundary that runs all around the circumpolar region is therefore a good datum to define the Arctic coverage limit.

III. RESULTS

Since the start of the Background Mission Arctic coverage, seven coverage campaigns have been completed. These are the summer and fall coverage of 2003, the winter, spring, summer and fall coverage of 2004, and the winter coverage of 2005 (Fig. 1, 2, 3 and 4), with the completion rates respectively of 90.8%, 85.3%, 90.6%, 77.8%, 98.9%, 85.9% and 81.4%. The variable completion rate is reflective of the degree of conflict with user requests. The completion rates are obviously lower during the seasons when other users, like the Canadian Ice Services, have a higher level of activity in the region for sea ice monitoring. The conflicts are often resolved by seeking favors from users of previously submitted requests. These favors or compromises may consist of choosing the same beam mode among the conflicting requests or foregoing a pre-planned swath by one or more of the requestors.

The Background Mission Arctic coverage is generally planned within the first two weeks of the first month following the onset of a new season, i.e. January, April, July and October. The coverage planning period for the Arctic Basin region does not exceed one week. The coverage planning is repeated only once for the lost swaths in the following week, before it is finally stopped. This strategy has been established to preserve the seasonal integrity of the datasets. Currently, the spring 2005 coverage is in progress. The RADARSAT-1 Extended Background Mission is intended to last until the end of satellite operations. A case will be made to continue the coverage with RADARSAT-2.

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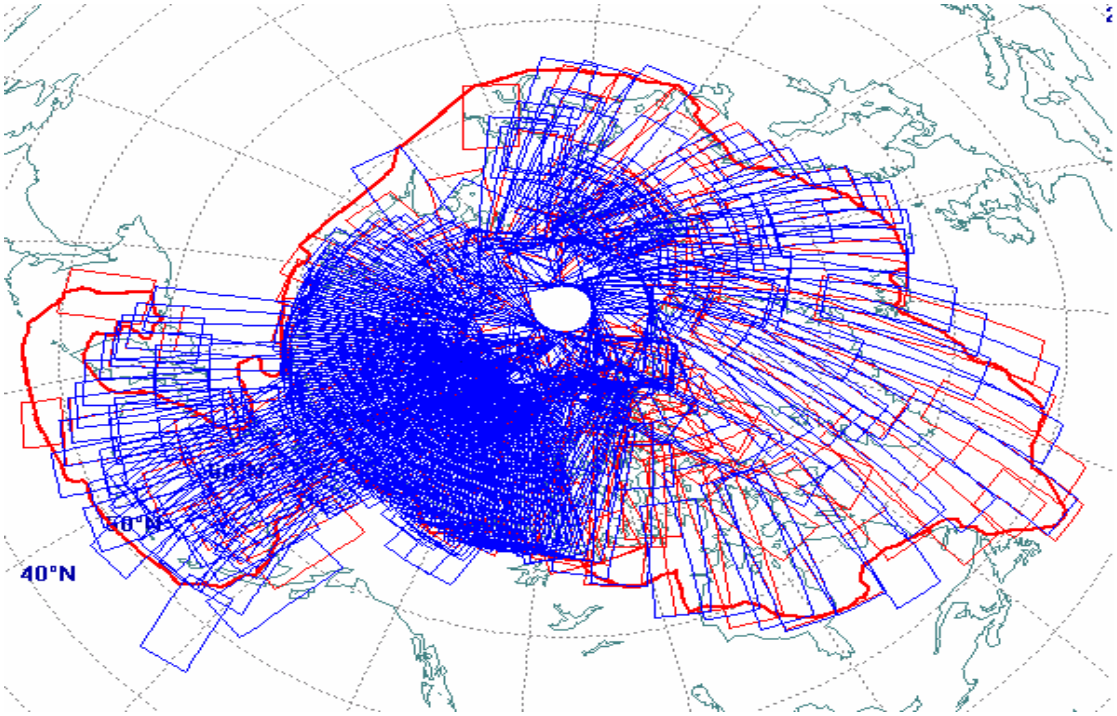

Figure 1. RADARSAT-1 Background Mission 2003 summer (red) and fall (blue) coverage of the Arctic Basin

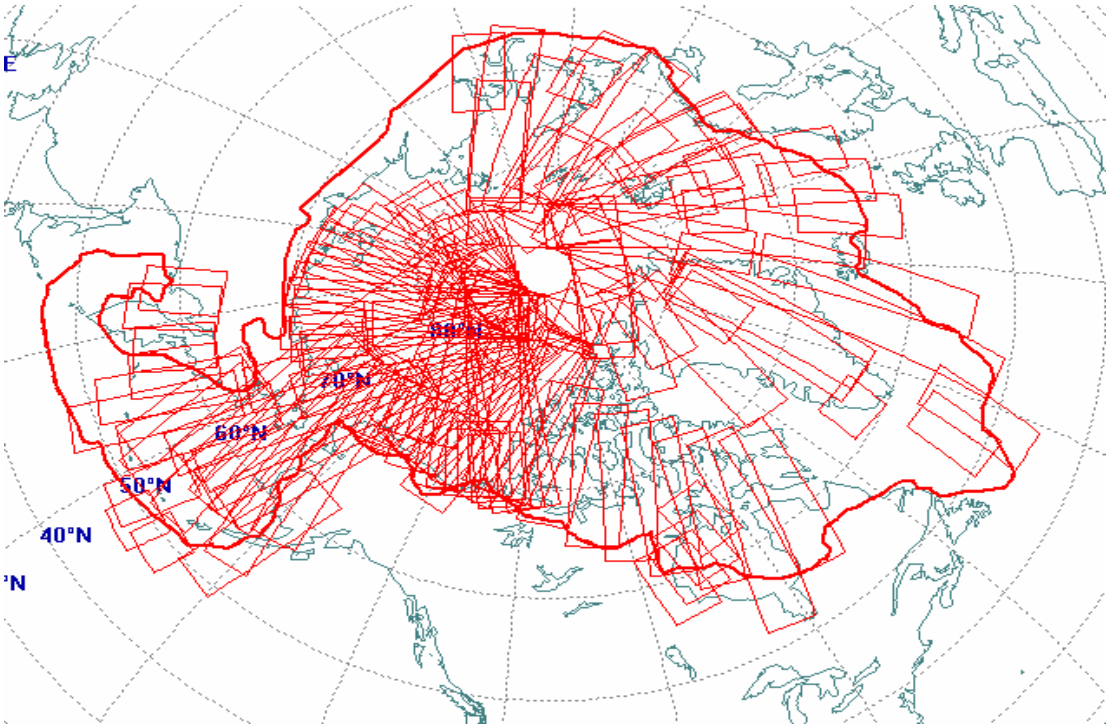

Figure 4. RADARSAT-1 Background Mission 2005 winter coverage of the Arctic Basin

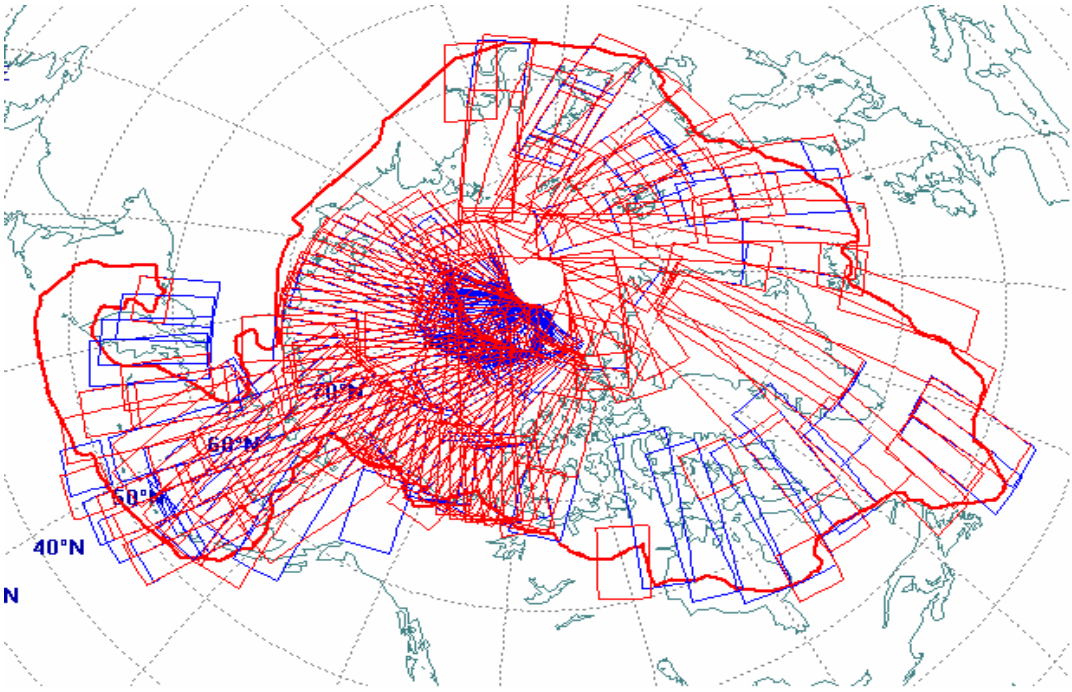

Figure 2. RADARSAT-1 Background Mission 2004 summer (red) and winter (blue) coverage of the Arctic Basin

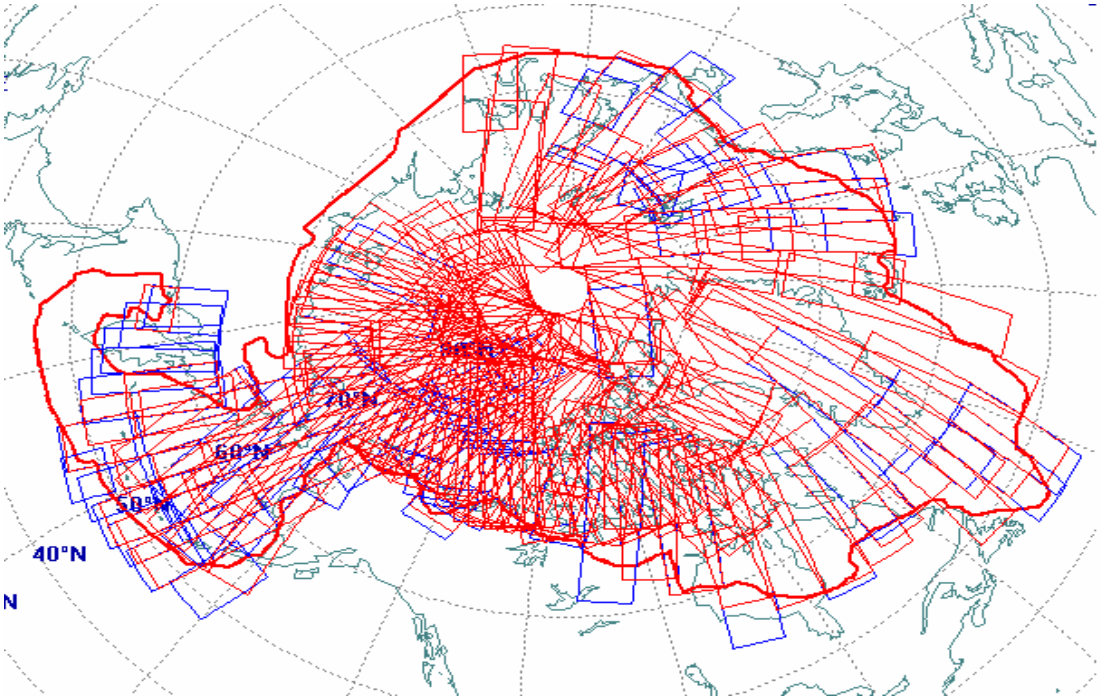

Figure 3. RADARSAT-1 Background Mission 2004 spring (blue) and fall (red) coverage of the Arctic Basin